

WHOLE AND PART METHODS IN TRIAL AND
ERROR LEARNING

BY
ELLA MAY HANAWALT

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN
THE UNIVERSITY OF MICHIGAN

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I. HISTORICAL REVIEW

One of the questions in the psychology of learning which experimentation has thus far failed to answer satisfactorily is that of the relative effectiveness of whole and part methods of procedure. By whole procedure is meant repetition of the material to be learned from beginning to end without interruption as many times as is necessary for the learner to attain a given standard of accuracy. Part procedure involves breaking up the material to be learned into parts, repeating the parts separately until each is learned, finally putting them together again, repeating the whole until the learner has attained the given standard of accuracy in reproduction. These are the pure whole and the pure part methods. In addition to these there have been suggested certain "mediating" or "modified" whole procedures, forms of whole procedure which lie between the whole and part procedures as defined above; and "modified" part procedures, which to a greater or less degree approach the whole procedure in character. Whether the whole procedure or some modification of it, or the part procedure or some one of its modifications is the best procedure to use in learning any given material has thus far not yet been conclusively determined.

In the attempt to evaluate these methods experimental work was done during the early years of the present century by a number of European psychologists, chief among whom were Ebbinghaus (6), Steffens, (30), Pentschew (19), Ebert and Meumann (8), Ephrussi (9), and Neumann (15) in Germany, and des Bancels (1) in France. The types of learning included in the studies of these investigators are rote learning (nonsense syllables) and meaningful learning (prose and poetry). In their conclusions they all agreed that, for most materials, learning by the whole method is more economical than learning by parts. Some of them did suggest, however, that in the use of material in which there is much inequality in the difficulty of parts or in which the length is such that attention cannot be fairly uniformly distributed over the entire body of material, it may be of advantage to use a modified whole method. Two such modifications

of whole procedure are described by Meumann (13) as follows: (a) "The whole body of material is divided into parts, the basis of division being the degree of difficulty of content; and the parts are marked off by a stroke or a blank space. In reading the series the reader pauses for a short time at the end of each section but he does not then return to the beginning of the section; instead he continues to read through to the end as in the case of the whole procedure." (b) With non-coherent material, such as the vocabulary of a foreign language, "the reading of the series of words progresses continuously until the learner observes that certain members of the series prove to be especially difficult. These he indicates by a written mark; he devotes special effort to learning them and then returns to the reading of the whole series,—continuing until the whole is uniformly memorized." But the general conclusion reached by these early experimenters is best expressed by Meumann (13) in these words: "General psychological considerations as well as experimental findings show that the whole method is the only one which is psychologically justifiable and that it is by far the most economical. That is, the whole method requires fewer repetitions and usually less time than the part method to produce a first errorless recitation; and what is still more important, the whole method secures a more accurate reproduction and more lasting retention."

In recent years experimental study of the relative effectiveness of the part and whole methods of learning has been renewed by British and American investigators, but the conclusions reached have not been as uniform as was the case with the earlier German and French investigators. On the one hand, Pyle (21), Pyle and Snyder (22), Lakenan (12), Brown (3), Sawdon (26), and Crafts (5) as experimenters, together with a host of writers of textbooks in psychology and education, favor the whole method; while on the other hand, Pechstein (16, 17, 18), Reed (23, 24, 25), Barton (2), Koch (11), and Winch (31) regard the whole method as inferior, some of them attacking it with not a little vehemence. The types of learning included in the studies of the group favoring part procedure are rote learning (nonsense syllables), meaningful learning (poetry) and trial and error learning (typewriting,

maze learning). The general conclusion of this group has been that the part method or some modification of the part method is superior to the method of the whole.

Summing up the advantages and objections which have been suggested or indicated by various investigators of the two procedures, we have the following:

Advantages of the whole method:

1. There is better distribution of attention and effort, keeping all associations of approximately equal strength until the maximum of efficiency is reached (8, 30).
2. Learning proceeds continuously in a forward direction so that no special act of learning is required in order to master any transitional portion (13).
3. The wholeness or unity of pattern (Gestalt) present in consciousness gives the material a coherence and meaningfulness which aid in fixing associations (13, 19).
4. Associations are formed in the way in which they are to be used and in no other way—
 - a. The association of each of the elements of the material in its proper relation, not only to the other elements, but also in its absolute position in the whole series, is retained and strengthened in each repetition (13, 30).
 - b. Associations between the individual elements of the learning material are formed in the direction and only in the direction in which they are to function in later reproduction (13, 8).
 - c. There are formed no unnecessary or incorrect associations which tend to interfere with the formation of correct associations (20, 30).
5. The rhythm employed is more suitable to the whole material (8).

Objections to the whole method:

1. There is confusion for the learner due to the fact that the length of the material exceeds his span of attention (23, 24).

2. For the learning effort expended upon the later portions of long material there are diminishing returns due to the fact that learning does not vary directly with the length of the material to be learned but that, rather, increasing the length of material increases disproportionately the difficulty of learning it (17).
3. The learner cannot readily see his own progress when he learns by the whole method (13).
4. There is waste of time caused by useless repetition of the known in order to master the unknown (24, 30).
5. Attention in the middle of the material, if long, tends to revert to earlier portions and the middle is less well impressed (8).

Advantages of the part method:

1. The length of the material is adjusted to the attention span of the learner (8, 24, 30).
2. The learner can see the progress he is making (13).
3. Positive helpful items of transfer (habits and attitudes) developed in the learning of one part carry over to the next in part learning more effectively than in whole learning (18).
4. Attention is renewed at the beginning of each part (8).

Objections to the part method:

1. Successive repetitions of a given part set up between the end of the part and its beginning conflicting associations which inhibit learning (13, 19, 24).
2. There is forgetting of one part while the next is being learned (19, 22).
3. A special act of learning is required to establish the connection between consecutive parts which have been mastered separately (13, 30).
4. The parts learned separately are incompatible when made to function as parts of the whole (16).
5. Temporal and spatial positional establishments acquired in learning by parts do not fit into the whole (18).

6. There is waste of time caused by useless repetition of the known in order to master the unknown. An early part is repeated more often than is necessary in order to make the connection between it and the next later part (24).
7. The rhythm employed on the part is not applicable to the whole (8).

From the above summary it is obvious that there is no clear agreement as to just what are the advantages of or objections to either of the methods of learning and certainly no approach to agreement among present investigators as to which is the superior procedure for any given type of learning material.

Of the investigations mentioned above, the only one which deals with whole and part procedure in trial and error learning and which uses animals as subjects is that of Pechstein (18), and it is this investigation that has suggested the present study. The animals used were white rats and the learning material was the maze. Pechstein's maze was four feet square with a food box eight inches square in the center. It was so constructed that it could be used as one whole maze or as four separate smaller mazes, each leading into the central food box. Each of the four parts was two feet square, contained 7 true alleys and 3 culs de sac and had a distance of 100 inches of true pathway and 36 inches of false pathway. In the entire maze there were 144 inches of false pathway and 400 inches of true. The arrangement of paths was such that there was a high degree of similarity in all the parts and the animal was required in each case to go as far as possible before making a turn and then to turn to the left wherever there was a real choice between paths. That is, he could avoid cul de sac 1 on the principle of going as far as possible before turning, and cul de sac 2 on the principle of turning to the left after having gone as far as possible and having arrived at a junction where a choice between paths had to be made. Culs de sac 3, 4, 6, 7, 8, 9, 10 and 11 could be avoided in the same manner as cul de sac 1; cul de sac 5 in the same manner as cul de sac 2. (Figure 1.)

The animals (rats) used by Pechstein were untrained in actual

maze running. A new group was used for each of the learning methods studied. At the age of eight or nine weeks, in order to accustom the rats to the feeding environment and to being handled, they were taken to the food-box for their regular feeding period of seven minutes each day and were allowed to run over the glass covering of the maze at will. This Pechstein regards as their period of training.

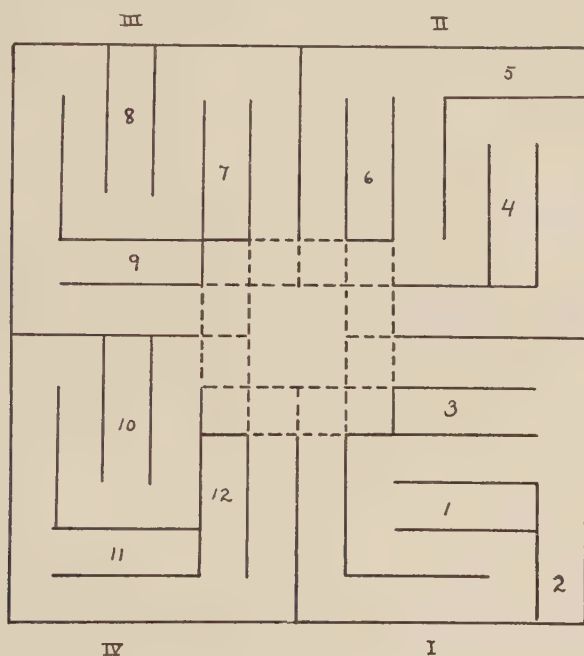


FIG. 1

The experiment was performed in a room electrically lighted, with one light directly above the center of the maze and another six feet from the main entrance of the maze. The experimenter sat behind the main entrance and may or may not have been visible to the rat, depending on the visual acuity of the animal and his position in the maze at any given moment.

Several aspects of Pechstein's experiment make it seem to the writer that it cannot be regarded as conclusive. In the first

place, his maze was so small that the whole of it can scarcely be considered a learning problem sufficiently difficult for adequate testing and comparison of methods, and certainly any one of the parts taken separately cannot be so considered. Moreover, the four sections are so similar in character that they do not in any case constitute four distinct learning problems. In addition to the general item mentioned above characteristic of all parts, namely, that the rat must follow the principle of going as far as possible and turning to the left wherever there is a real choice of paths, there are other specific items of similarity in the various parts of the maze. For instance, the last path in each section, the path which leads into the food-box, is identical in length and character; and, with the exception of section IV, this is true also for the first paths, those leading out of the food-box. In sections I and II the first two of the seven true paths are identical in length and type. In sections III and IV the first three true paths are likewise identical, and in section III the third to the seventh true paths inclusive are like the first to fifth in section IV in regard to distances involved, position and direction of successive turns to be made, and culs de sac to be avoided. Such similarities in the specific character of parts render questionable any conclusion regarding the compatibility of parts functioning in any combination or in the whole. The inequality of illumination in various parts of the maze and the presence of the experimenter within the possible view of the animal while running may or may not have exerted an influence on learning. They are, at best, factors which are uncontrolled and which render results and conclusions less reliable than they would be had the experiment been conducted under fully controlled conditions. Possibly the greatest criticism of Pechstein's experiment is that his rats were in each test untrained and that what he designates as their period of learning was in reality a period of training. What he calls "transfer items"—general maze habit, consciousness of power and favorable emotional tone—which he believes operate at their full value in part procedure but not in whole procedure, are simply variables which can be eliminated through preliminary training of animals before serious experimentation is begun. When these

variables have been eliminated through training, then the experimenter may be sure that the learning is learning of the specific maze pattern involved and of that only. Otherwise the interpretation of the results is of doubtful validity.

Six methods were tested and compared in respect to number of trials, number of errors, and amount of time required to learn to the point that four out of five successive trials were run without error. The methods used were the whole method: Parts I-II-III-IV run in each trial; the pure part method: Part I learned, then II, then III, then IV, and then I-II-III-IV; the progressive part method: Part I, then II, then I-II, then III, then I-II-III, then IV, then I-II-III-IV; the direct repetitive part method: Part I, then I-II, then I-II-III, then I-II-III-IV; the reversed repetitive part method: Part IV, then III-IV, then II-III-IV, then I-II-III-IV; and the elaborative part method: Part I, then II, then III, then IV, then tests on I-III, II-IV, IV-I, III-I, and IV-II. The conclusion reached was that "the complex motor problem is probably always best mastered by one of the several 'modified part' methods. The one universally to be preferred is the 'progressive part' " (18).

II. PROBLEM AND PROCEDURE

A. Statement of purpose

The experiments of all the earlier German and French investigators have been restricted entirely to the study of whole and part procedure in the learning of rote and meaningful material. The subjects have necessarily been human. We are indebted to Pechstein for the one research which has to do with whole and part procedure in trial and error learning with animal subjects, a timely piece of pioneer work in an important field. Pechstein's study has proved to be a very stimulating and suggestive one but, like much pioneer work, is fraught with certain types of imperfections which we have learned to avoid by the use of such improved materials and technique as have been developed during the years since his study was made.

The purpose of this study is, therefore, to repeat the experimental study of Pechstein in whole and part procedure in animal

learning, attempting to improve upon it in the following particulars:

The use of mazes which are more distinct in whole and in parts and which will more readily test the methods of learning employed.

Better control of the objective conditions of the experiment.
The use of trained subjects.

B. Description of apparatus

The apparatus employed was the maze in the University of Michigan psychological laboratories, designated by Cameron (4) as the "Shepard universal type," designed by Dr. J. F. Shepard and briefly described by him (28).

The maze is set up on a platform 15 feet square, reinforced from beneath to prevent warping and sagging and mounted on large casters to permit of its being moved with reference to overhead lighting and other conditions. It is placed in a windowless room built especially for the purpose, located in the ground floor of the building to prevent vibration.

The maze itself is constructed of unit materials, completely interchangeable, permitting an almost unlimited variety of patterns. Wooden posts, $1\frac{3}{4}$ " square and 14" high, are set into the floor of the maze in rows, $11\frac{1}{2}$ " apart on centers. Removable posts, similar in cross-section but only $7\frac{1}{2}$ " high are placed as needed midway between the taller ones and in line with them (Figure 2). The four vertical surfaces of all posts are grooved and into these grooves are fitted small panels of five-ply veneer, $7\frac{1}{2}$ " by $4\frac{1}{2}$ ", which form the walls of the alleys. Both posts and panels are painted a battleship gray.

The floor of the maze is covered with a black waterproof asphaltic linoleum-like material $\frac{3}{16}$ " thick and laid in sections $11\frac{1}{2}$ " by $11\frac{1}{2}$ " with the corners cut out to fit into the stationary posts.

The entire maze is covered with removable $\frac{1}{2}$ " mesh wire screen cut into 3' by 3' sections. At intervals of $11\frac{1}{2}$ " holes are cut into the screen which allow the taller posts to slip through them and the screen itself to rest upon the panels and lower posts. The

sections of wire screen are clamped to the taller posts with No. 10 L E B binder clips, which hold them firmly in place.

Each alley of the maze is $5\frac{1}{2}$ " wide (4" between posts). The distance from center to center of posts has been taken in this problem to represent a unit of maze distance. The entire maze, therefore, is 30 units square.

The starting point A in the maze is simply the first unit of the first path and is opened when inserting the animal for a run by

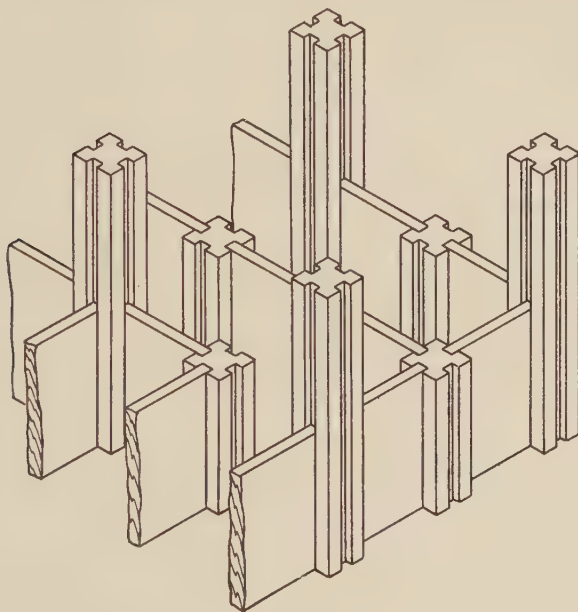


FIG. 2

sliding the panel up. The last true path leads directly into the food-box B. The food-box is 14" in height and is formed by placing panels 14" by $10\frac{1}{4}$ " between adjacent posts. It contains two compartments. The first and larger compartment, 3' by 1', is the one into which the animal comes directly from the maze for the nibbles of food which he is allowed between the successive runs. The second smaller one, 1' by 1', is the one into which he is placed for his regular daily feeding period at the end of his last

run. The second is separated from the first by a panel which may be opened by sliding it up and down in the grooves into which it is fitted.

The entire apparatus is illuminated by 100 flashlight lamps spaced 2 feet o. c. in each direction and suspended 3' above the maze on a frame made of wire and of wood trusses. Each lamp is covered above and at the sides by a wooden shade 5" square and 2" deep. This arrangement of the lamps makes the illumination in all parts of the maze uniform and insures against any variations in lighting conditions which might serve as differential cues to the learner. Above the lighting apparatus is a screen of one thickness of cheese-cloth which serves to protect the maze from any foreign articles or substances which drop down from above.

The ceiling of the maze room is about 15' above the maze and opens into the room above by means of a 3' by 3' aperture. The animal was observed through this aperture while the experiment was in progress; at other times the aperture was closed by means of an iron trap door. The upper room from which the observations were made is a dark room. The illumination used by the observer while taking records was obtained from two 25-watt red lights so shaded that the rays could not fall through the aperture in the direction of the maze.

Five pairs of maze patterns were used,² ten mazes in all. They were first charted on graph paper, the details planned to fit the particular learning methods to be tested, and then constructed on the maze platform as designed. Each maze was built in such a way that it could be used as a single whole maze or as four separate smaller mazes or parts, each leading into a food box. For certain learning methods (pure part, progressive part, and direct repetitive part) it was necessary to have two food boxes, into one of which the animal came from Parts I and II and into the other of which the animal came from Parts III and IV. These were located from the point of view of the observer, at the upper and lower left corners of the maze. In each of the four parts of a maze there were 4 sections of true pathway, each containing

² Diagrams of all mazes used in this study may be found in the manuscript on deposit in the University of Michigan Library.

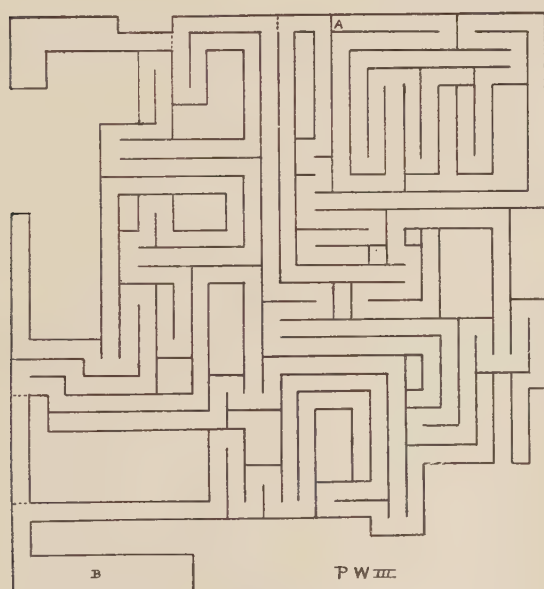
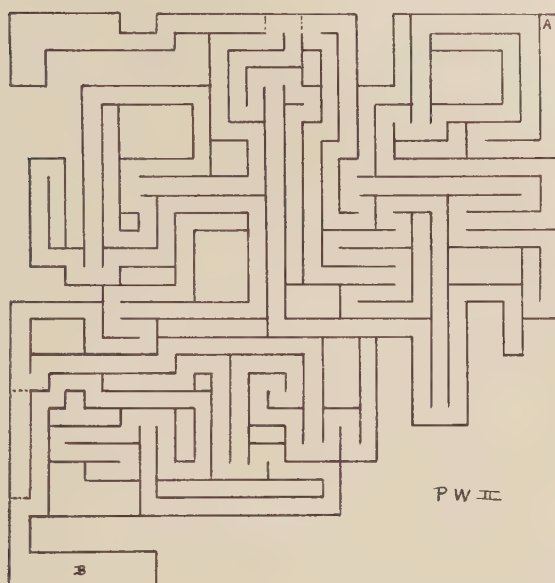


FIG. 3

several alleys, and 3 sections of false pathway, each containing 3 alleys. The first true pathway of Parts II, III, and IV was in each case a continuation of the last true pathway of the preceding part, so that when a maze was used as a whole it contained 13 sections of true pathway of from two to ten alleys each and 12 sections of false pathway of three alleys each. For any one part the amount of true pathway was approximately 100 units and the amount of false pathway approximately 40 units, making a total of approximately 400 units of true and 160 units of false pathway in the whole maze.

There were 12 junctions at which choices between paths had to be made. All junctions were of the same character, requiring the animal to approach through a central alley and to choose between a left and a right turn. The directions of successive turns within any given pathway and the directions of turns at successive junctions were so planned that no rhythm of movement could be set up by the animal which might serve as a cue in making these choices.

Each maze was designed with the idea in mind of avoiding any similarities among the parts of a given maze or among the different mazes in respect to arrangement of pathways, lengths and positions of alleys in corresponding regions, directions of turns, or locations of places of option between alleys, which might affect either positively or negatively the learning of any other maze or part of a maze.

C. The animals used

The animals used were male albino rats, 15 in all. Most of them were bred in the laboratory, a few were secured from a near-by dealer and two from Wistar Institute of Anatomy and Biology in Philadelphia. They were housed in a room adjoining the maze room, in cages of wood and wire, each rat in a cage by himself. They were provided with bedding of wood shavings. Their food consisted of McCollum's diet and well selected table scraps mixed with cod-liver oil. Each rat was allowed a few nibbles of food in the first compartment of the food-box at the end of each run and at the end of his last run for the day was placed

in the smaller compartment of the food-box for the remainder of his daily feeding period. He was allowed to eat as much as he wished unless, as sometimes happened, the character of his work indicated that he was not hungry enough to run consistently, and then the amount was decreased.

All animals had run mazes of comparable difficulty but of different patterns for periods ranging from one to ten months before this experiment was begun. All of them, therefore, were thoroughly accustomed to the maze situation, to human handling and feeding in the food-box. They were "at home" in the situation; it had become a natural one for them, and those variables necessarily present when the animal is placed in an unfamiliar situation—lack of general adaptation, absence of food associations, and emotional disturbance—had been eliminated through the training process.

D. General procedure

After a period of 11 days of practice on a preliminary maze (PW I) planned for the purpose of accustoming the rats to the type of maze to be used and of accustoming the experimenter and recorders to the procedure to be employed, the experiment proper was begun.

Five types of part procedure in learning were compared with the whole procedure. These were designated, borrowing the terms used by Pechstein, as the pure part, the progressive part, the direct repetitive part and the reversed repetitive part methods, the fifth method being a modification of the reversed repetitive part method. In the whole method, each rat ran the entire maze from the starting point A to the food-box B in each trial. In the part methods the order of parts learned was as follows:

Pure part: Part I, then II, then III, then IV, then I-II-III-IV.

Progressive part: Part I, then II, then I-II, then III, then I-II-III, then IV, then I-II-III-IV.

Direct repetitive part: Part I, then I-II, then I-II-III, then I-II-III-IV.

Reversed repetitive part: Part IV, then III-IV, then II-III-IV then I-II-III-IV.

For each part or whole maze the criterion for learning was arbitrarily set at three successive runs without error. In the modified reversed repetitive part method eight trials were given each rat on each of the part combinations and then, regardless of the degree of learning attained, he was set to running the maze as a whole and kept at it until the standard of learning was reached.

The experiment was divided into five parts, the whole procedure being compared in turn with each of the five part procedures employed. Two mazes were used in making each comparison. The rats were separated into two groups called the whole group and the part group. In the first maze of each pair the whole group learned by the whole method, the part group by a part method; in the second maze of the pair those rats which had previously belonged to the whole group formed the part group, and those which had constituted the part group became the whole group. Thus, in comparing the whole method with any given part method, each rat learned one maze by the whole and one by the part procedure. The purpose of this arrangement was to even out any individual differences which there might be in the learning ability of the rats (and there were clearly such differences) and to even out any differences in the difficulty of learning which might be present due to the differences in character of detail in the various maze patterns (though every effort was made in designing the mazes to make them equal in degree of difficulty).

The experimenter, after placing the dish of food in the first compartment of the food-box, brought the rat from his cage in the adjoining room into the maze room, placed him in the maze at the starting point A and then, until the run was completed, stood or sat in a position beyond possible visibility to the rat. This procedure was repeated until the rat had made his required number of runs. Then he was placed in the smaller compartment of the food-box to finish his meal and the next rat was brought in and run in the same way. During the learning period each rat was kept as nearly as possible equal to all the others in amount of work done until the required standard of learning was reached. A rat learning the whole maze was given 2 runs per evening; one learning a single part or a quarter was given 8 runs; one learning

a combination of 2 parts was given 4 runs; and one learning a combination of 3 parts was given 2 or 3 runs depending on whether his total runs the preceding evening had amounted to one quarter more or less than those of the other rats. When all rats had reached the point where they were running the whole maze, the number of runs for each one was increased to 4, then to 6, then to 8 per evening until he made his three successive correct runs, when it was again dropped to two.

An effort was made to preserve in full the trial and error character of the learning problem and with this object in mind the procedure of preventing returns was omitted. Trial and error learning differs from a mere memory process with either nonsense or meaningful material in the mode of control of the successive events involved. In the latter type of learning the series of primary events is objectively determined; in trial and error learning the order is, within the limits, determined by the learner. In the present investigation there has been no interference on the part of the experimenter with the order of events possible within the maze concerned; the selection has been entirely by the animals themselves.

A record of each run for each rat was kept by a recorder, who lay on a mattress on the floor of the room above and observed the rat through the aperture which connected that room with the maze room below. The recorders were upper class and graduate students selected from among those who were taking the course in comparative psychology. Each recorder was given a period of training before he was permitted to take permanent records for the experiment. He was required to know thoroughly each maze and, by means of a system of symbols which he had learned, to keep for each run of each rat a record which outlined precisely the path taken and indicated where the animal hesitated, stopped or looked into the wrong alley, where he started or entered into the wrong alley and how far, where he played in the pathway, and where he retraced in the true path. Using a stopwatch, the recorder took time on the rat from the moment he entered the last alley of the first pathway until he entered the food-box. This obviously gave a margin of advantage in the item of time to the

rats of the part group as long as they were running a part of the maze. The time spent in the early alleys of the first pathway of each part was not counted as a part of the total learning time, while with the whole group, only the time spent in the early alleys or the first pathway of the maze was omitted. It was necessary, however, to give an advantage in this item to one group or the other owing to the tendency of rats to play in the first few alleys for some seconds before starting to run seriously. During the time that a rat was in the maze absolute silence was observed by both experimenter and recorder.

The question arose as to whether or not, in the learning of any part or part combination by rats of the part groups, the last three perfect runs required as evidence of mastery of that portion of the learning problem should be included in determining the total amount of energy necessary for learning the maze by that procedure. After careful consideration it was decided that they should be included. In the first place, they are an essential part of the method. But a more important consideration is the fact that the repetitions involved do function later in the learning of the whole, even though they may be regarded as over-learning for the immediate part combination concerned. This, of course, raised the question of the relative value of those repetitions in excess of what are necessary for perfect performance (over-learning) for the purpose of relearning later (savings method). The writer knows of no investigation of this question with reference to rats learning a maze. It is, however, a question of memory and there have been some investigations of it as it applies to the human subject learning nonsense syllables. Both Ebbinghaus (7) and Mibai (14) found that all repetitions of nonsense syllables were of equal value; Ebbinghaus found it to be true even of those which were involved in over-learning; and thus far their findings have not been successfully challenged. The results of the present group of experiments have been tabulated and averages computed both with these runs included and with them excluded, and in each case the ultimate advantage has proved to be in favor of the same procedure (Section IV).

The following items regarding each trial of each rat were tabulated:

The number of the trial.

The part or parts of the maze run.

The time required for the run.

The number of errors of each of the following kinds:

Retracing in the true path.

Culs de sac taken while going in a forward direction.

Culs de sac taken while going in a backward direction.

The excess distance travelled

In the true path.

In the false path.

The total distance travelled.

Finally the whole procedure was compared with each of the part procedures used in respect to the number of trials required, the amount of time taken, the number of errors made, the units of excess distance travelled, and the units of total distance travelled until the learning was complete, that is, until each of the animals had made three successive runs through the entire maze without error.

It is fully recognized that these criteria are not of equal value in determining the relative effectiveness of the various procedures tested. The one regarded as most significant in this problem is that of the total distance travelled. This criterion includes both the number of trials and the units of excess distance travelled in each trial and is, more than any other single criterion or combination of criteria, a true measure of the amount of energy spent in learning.

III. RESULTS OF EXPERIMENTS

A. Comparison of whole with pure part procedure

One pair of mazes and 8 rats were used to compare the relative effectiveness of the whole and pure part procedures in learning. The first maze, PW II, contained 349 units of true pathway and 150 units of false pathway; the second, PW III, contained 388 units of true and 153 units of false pathway. In learning the

first maze the rats numbered 60, 68, 69, and 70 constituted the "whole" group and those numbered 54, 64, 66, and 71 constituted the "part" group. In learning the second maze the groups were reversed.

For each maze the procedure was as follows: each rat of the "part" group was run in Part I of the maze 8 times per evening until three successive correct runs had been made. Then he was transferred to Part II until the same standard of success had been attained, likewise in turn to Part III and Part IV. When all four parts had been learned, the rat was run on the whole maze two times per evening. Each of the rats of the "whole" group ran the entire maze two times per evening until all the rats of the part group were ready to be put upon the whole. Then the number of runs was increased for all rats that had not yet completed the learning. Eleven evenings were spent on each of the two mazes. The general procedure employed was that described in Section II D.

The learning of the parts singly by the part group and of the whole maze by the whole group proceeded in the way usual with trained rats. The rats started out promptly and, after the first few alleys were passed, ran rapidly until the food-box was reached, though with hesitations at junctions and with frequent errors in choice of paths. Hesitations and errors were gradually eliminated and finally the three consecutive correct runs were completed.

When the rats of the part group were transferred from Part IV to the whole, their behavior was different. They stopped at the transitions between parts, often for many seconds, nosing and pawing at the panel blocking the opening which had previously led into the food-box. Sometimes, after this period of futile effort to get through, they retraced into the preceding section, but more often they went on into the next section of the maze and repeated this behavior at the next point of transition. But there was little evidence of recognition of any of the parts as having been learned before. The first few runs on the whole were in character very much like the first runs of the same rats on any new maze except for the hesitations at transition points.

In studying the pure part procedure it is of interest to compare the effort expended upon learning the parts separately with that expended upon the act of combining the parts into the whole. Using as criteria the amount of time, the number of trials, the number of errors and the number of units of total distance travelled, the results show that the amount of energy required was greater in terms of time, trials and total distance, but less in terms of errors, for combining the parts after they had been learned singly than for learning them singly originally. The percentages obtained are as follows:

	PW II		PW III		PW II AND III	
	Parts singly	Parts combined	Parts singly	Parts combined	Parts singly	Parts combined
Time	37.8%	62.2%	36.9%	63.1%	37.35%	62.65%
Trials	35.0	65.0	31.5	68.5	33.25	66.75
Distance	39.2	60.8	33.7	66.3	36.21	63.79
Errors	57.1	42.9	53.9	46.1	55.50	44.50

In only one respect, then, did the act of connecting the parts already learned appear to be less difficult than the act of learning them separately, in respect to number of errors made. An examination of the units of excess distance represented by these errors reveals that in PW III there were even more units of excess distance taken in the process of combining the parts into the whole than in the act of learning them singly, though the difference was very slight (.1%). It is evident that in learning by the pure part method approximately two-thirds of the energy of the learners was spent upon the task of combining into a whole the parts which had already been learned singly. Notwithstanding the fact that more energy was required to combine the parts than had been required to learn them singly, it is clear that some learning was retained from having run the parts separately, for the amount in time, errors, trials and total distance was in general less for the parts groups in running the whole maze than for the whole groups.

Table I gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of

TABLE I

		PW II		PW III	
Group of rats.....		Part	Whole	Part	Whole
Number of trials.....	Parts	<u>37.25</u>		<u>40</u>	
		4		4	
	Whole	17.25		21.7	
	Both	26.56	22.2	31.7	20.5
Time.....	P	15' 48.27''		20' 17.0''	
	W	26' 49.92''		34' 35.4''	
	B	42' 38.19''	40' 13.3''	54' 52.4''	38' 6.5''
Number of errors:					
Retracing in true path.....	P	8.75		6.0	
	W	2.75		7.0	
	B	11.50	5.7	13.0	6.0
Blind forward.....	P	37.50		30.5	
	W	33.30		22.5	
	B	70.80	59.2	53.0	39.0
Blind backward.....	P	3.75		2.2	
	W	1.50		3.5	
	B	5.25	2.0	5.7	3.5
All kinds.....	P	50.00		38.7	
	W	37.50		33.0	
	B	87.50	67.0	71.7	48.5
Number of units of excess distance:					
In true path.....	P	352.0		209.5	
	W	160.5		338.5	
	B	512.5	200.0	548.0	292.0
In false path.....	P	783.7		646.5	
	W	605.5		520.7	
	B	1389.2	1182.7	1167.2	821.7
Total.....	P	1135.7		856.0	
	W	766.0		859.2	
	B	1901.7	1382.7	1715.2	1113.7
Number of units of total distance traveled.....	P	4384.89		4736.0	
	W	6786.25		9278.8	
	B	11171.14	9130.5	14014.8	9067.75
Rats used.....		54, 64, 66, 71	60, 68, 69, 70	60, 68, 69, 70	54, 64, 66, 71

errors of each type, number of units of excess distance taken in the true pathway and in the false pathway, and number of units of total distance travelled. In order to make the number of trials for learning required by the part group comparable to that required by the whole group, the trials of the part group were reduced to whole equivalents. This was done by dividing by 4 the total number of trials spent on parts and adding to that quotient the number of trials spent in combining the parts into the whole. Errors were classified into three types—retracing in the true path, culs de sac taken while running in the forward direction, and culs de sac taken while running in the backward direction in the maze. Starts and actual entrances into culs de sac were counted as errors of the second and third types, depending on the direction in which the animal was running at the time. The number of units of total distance travelled was computed by the formula: numbers of trials $\times$ length of true pathway + excess distance travelled.

Examination of these data shows that in every particular the whole groups were superior to the part groups in learning the mazes. With a few exceptions in a few items this was true for individuals as well as for groups. Comparing for individuals the energy spent in learning one maze by the whole method with that spent in learning the other maze by the part method, in the results obtained from three rats there were differences in favor of the part method in some of the items: Rat 64 took more trials by one and more units of total distance in learning PW III by the whole method than in learning PW II by the pure part method; Rat 60 made more errors of the blind-forward type and took more units of distance in the false pathway in learning PW II by the whole method than in learning PW III by the pure part method; Rat 68 took more time, more errors of the blind forward type, more total errors, and more units of excess distance in the false pathway in learning PW II by the whole method than in learning PW III by the pure part method. None of these differences in favor of the pure part procedure were large, however, and all of them were greatly overbalanced by the many times larger number of items showing a contrary result, even with

these three rats, and by the amount of the differences in favor of the whole procedure for all other rats.

Table II gives the average differences in favor of the whole procedure for each of the mazes separately and for both combined in absolute amounts and in percentages. It will be seen that by whatever criterion the two methods are compared there was an advantage for the whole—25.8% in number of trials, 18.0% in amount of time, 27.8% in number of errors, 31.1% in number of units of excess distance, and what is most important of all, 26.7% in number of units of total distance travelled.

TABLE II

	PW II		PW III		PW II AND III	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials.....	4.36	16.4	11.2	35.3	7.78	25.8
Time.....	2' 24.89"	5.6	16' 46.00"	30.5	9'35.44"	18.0
Errors:						
Retracing in true path....	5.8	50.4	7.0	53.8	6.4	52.1
Blind forward.....	11.6	14.9	14.0	26.4	12.8	20.6
Blind backward.....	3.25	61.9	2.2	38.6	2.72	50.2
All kinds.....	20.6	23.4	23.2	32.3	21.9	27.8
Excess distance:						
In true path.....	312.5	61.1	256.0	46.9	284.2	54.0
In false path.....	206.5	14.8	345.5	29.6	276.0	22.2
Both.....	519.0	27.2	601.5	35.0	560.2	31.1
Total distance.....	2040.64	18.2	4947.1	35.2	3493.87	26.7

Attention has been called to the fact that each maze pattern was designed with the idea in mind of avoiding similarities among parts of the same maze as well as among mazes; that is, each part was unique, so that there were no details of one pattern which might carry over either to facilitate or to interfere with the learning of the next. Moreover, the animals used were thoroughly trained and this was done for the purpose of reducing the variables to one only, that of the specific maze pattern involved. It is interesting to note that with these factors under control,

there was no evidence of increasing readiness on the part of the rats to attack successive new mazes and no consistently increasing facility exhibited in the learning of the new mazes. The order of difficulty, from least to greatest, in learning the four parts of the maze PW II when measured by average amount either in trials, time, errors or total distance was II, I, III, IV. For PW III, when measured by average amount in trials, time or total distance, the order was II, IV, I, III; when measured by average number of errors it was IV, II, I, III. There were variations from this order for individual rats on each maze, but in no instance was the order either I, II, III, IV or IV, III, II, I in any item. In other words, there is no evidence that the learning of one part either aided or hindered the learning of any later part in respect to the time or energy required; each part appears rather to have constituted a distinct unique learning problem in itself unaffected by any other part.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the pure part procedure in this study we find

1. That the whole procedure was superior, whatever be the criterion applied. In respect to total distance travelled, which is the truest measure of energy expended, the advantage for the whole procedure was 26.7%.
2. That in the pure part procedure learning the parts constituted approximately $\frac{1}{3}$ and learning to combine the parts into the whole approximately $\frac{2}{3}$ of the learning activity.
3. That, when all criteria are taken together, learning the parts singly first did appear to reduce somewhat the amount of energy required to master the whole later, though there were many exceptions in different items for individual animals.
4. That, when all factors are adequately controlled, the learning of one part or of one maze did not affect either positively or negatively the learning of later mazes.

B. Comparison of whole with reversed repetitive part procedure

One pair of mazes and ten rats were used in testing the relative effectiveness of the whole and reversed repetitive part procedures

in learning. The first maze of the pair, PW IV, contained 394 units of true and 152 units of false pathway; the second, PW V, contained 413 units of true and 157 units of false pathway. In learning PW IV the rats numbered 60, 62, 68, 69, and 70 constituted the whole group and those numbered 54, 64, 66, 71 and 73 constituted the part group. In learning PW V the groups were reversed.

For each maze the procedure was as follows: each rat of the part group ran Part IV of the maze 8 times per evening until three successive correct runs had been made. Then Part III was added and the rat was required to run Parts III and IV together 4 times per evening until the same degree of mastery had been attained. Likewise in turn he was transferred to Parts II-III-IV together running these sections 3 or 2 times per evening; and finally to the whole running it 2 times per evening. With each transfer he ran first a new section of the maze and then one or more already learned sections, a procedure requiring not only the mastery of the new, but along with it, a review of the old in each case. Each of the rats of the whole group ran the entire maze two times per evening until all the rats of the part group had been transferred to the whole. Then the number of runs was increased for all rats which had not yet completed the learning. Nineteen evenings were spent on the maze PW IV and eighteen evenings on PW V. The general procedure was that described in Section II D.

The behavior of the rats of the part groups in learning Part IV and those of the whole group in learning the mazes as a whole proceeded in the way described above for similar learning in mazes PW II and PW III. When the rats of the part groups were transferred from Part IV to Parts III-IV, they attacked the new learning problem with the usual eagerness and with the usual hesitations and errors in choice at junctions. Upon reaching the point of transition from Part III to Part IV, at first most of the rats hesitated before proceeding into Part IV, but these hesitations at the points of transition were generally dropped after a few runs. In no instance did the animal in his first trial after being transferred to a new part run the already learned and sup-

posedly familiar section as if he recognized it. Of the total of 30 times that rats were transferred from one part (IV, III-IV, or II-III-IV) to the preceding one there was just once that the run through the already learned section of the maze was without error, and even in that instance it was not free from hesitation. After the transfer to the whole, when each rat had had the maximum of review of the already learned sections, the first run of all rats excepting one (Rat 71) were in character very much like the first runs of the same rats on any new maze. From 1 to 9 trials were required before any of the other rats made a run from the beginning free from error in the already learned parts, the average for the two mazes being 3 trials. Most of these errors were made in the part learned latest and the rats often showed evidence of recognizing earlier learned portions of the maze before reaching the food-box. That there was some learning retained from having learned the last three sections by this reversed cumulative method, however, is indicated by the fact that the amount in trials, time, errors and total distance is in general very much less for the rats of the part group after they were set to running the maze as a whole than for the rats of the whole group.

Table III gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance taken in the true pathway and in the false pathway, and number of units of total distance travelled. Errors were classified and counted and number of units of total distance computed as before. Examination of these data shows that in every particular (except excess distance in true pathway in PW IV) the whole groups were superior to the part groups in learning the mazes. With very few exceptions this was true for individuals as well as for groups. In the results obtained from two rats there were differences in favor of the part method in a few of the items: Rat 62 took more trials, more time and more errors of the blind-forward type in learning PW IV by the whole method than in learning PW V by the reversed repetitive part method; Rat 69 made more errors by 1 of the blind-backward type in learning PW IV by the whole method

TABLE III

Group of rats.....	PW IV		PW V	
	Part	Whole	Part	Whole
Number of trials.....	Parts			
	Whole			
	Both			
Time.....	143		103.75	
	4		4	
	14		14.8	
	49.75	33.6	40.7	18.0
Time.....	1 hr. 2' 39.47"		57' 26.66"	
	24' 54.38"		30' 31.14"	
	1 hr. 27' 33.85"	1 hr. 12' 11.3"	1 hr. 27' 57.80"	30' 13.52"
Number of errors:				
Retracing in true path.....	P		11.4	
	W		7.8	
	B	16.6	19.2	5.0
Blind forward.....	P		48.6	
	W		24.4	
	B	50.75	73.0	42.8
Blind backward.....	P		4.8	
	W		3.0	
	B	4.0	7.8	2.0
All kinds.....	P		64.8	
	W		35.2	
	B	71.35	100.0	49.8

Number of units of excess distance:					
In true path.....	P	546.0		1093.6	
	W	413.4		905.2	
	B	959.4	1006.2	1998.8	266.0
In false path.....	P	1380.0		1234.6	
	W	447.6		542.4	
	B	1827.6	1133.6	1777.0	981.2
Total.....	P	1926.0		2328.2	
	W	861.0		1447.6	
	B	2787.0	2139.8	3775.8	1247.2
Number of units of total distance traveled.....					
	P	16011.5		13040.4	
	W	6377.0		7560.0	
	B	22388.5	15378.2	20600.4	8681.2
Rats used.....					
		54, 64, 66, 71, 73	60, 62, 68, 69, 70	60, 62, 68, 69, 70	54, 64, 66, 71, 73

than in learning PW V by the reversed repetitive part method. The number of units of excess distance due to retracing in the true path was so great for these two rats, which happened to be in the same group, that in one of the mazes (PW IV) the average for their group (whole group) in this item was somewhat greater than for the other group. These differences, however, excepting in the number of trials required by Rat 62 for learning, were so small that they are insignificant. In general, the differences in favor of learning by the whole method were considerably greater when the whole method was compared with the reversed repetitive part method than when it was compared with the pure part method.

Again it is of interest to note the relative amount of learning effort devoted to the parts and to the whole in this part procedure. It is, of course, impossible to determine just what proportion was expended on learning each part separately or just what proportion was expended on combining the parts already learned, but it is possible to determine the proportion given to the learning of Parts II, III and IV and that required to complete the learning by adding Part I. The results obtained from the two mazes show that for all of the part combinations taken together, for each of them separately, and for the learning of the whole by the addition of Part I, the proportions expressed in terms of the criteria we have been using were

	PART IV	PART III-IV	PART II-III-IV	PART COM- BINATIONS	WHOLE
Trials	5.2%	19.8%	43.0%	68.0%	32.0%
Time	5.7	21.8	41.0	68.5	31.5
Errors	7.2	24.3	36.8	68.3	31.7
Excess distance	6.4	23.0	35.4	64.8	35.2
Total distance	5.4	20.6	42.0	68.0	32.0

As these percentages indicate, all of the criteria employed give fairly consistent results in the measurement of the amount of energy expended by the rats of the part groups in each of the learning acts involved. It will be observed that to learn the part combinations became increasingly difficult through the first three

learning acts (IV, III-IV, and II-III-IV). This was true, not only for groups, but also for individual rats with the exception of Rats 66 and 71 which had proportionally more difficulty in combining Parts III and IV than in combining Parts II, III and IV. Up to the point where Parts II, III and IV had been successfully combined, the proportion of energy expended by the rats of the part groups was approximately only $\frac{2}{3}$ of the total amount of energy required for complete learning, though it had already exceeded that required for learning by those of the whole groups. It is not easy to explain just why the problem for the rats of the part groups increased in difficulty as part combinations became more complex through three learning acts and then proved to be less difficult in the fourth and most complex combination of all. It may have been due to the excessive number of repetitions given the II-III-IV combination before it was mastered which resulted in fixing the series of reactions so securely that they were retained better than the preceding series had been. Or it may be due (and this is more probable) to the fact that when the rats of the part group were ready to run the maze as a whole the number of trials per evening was increased gradually from two to six. That is, the decrease in amount of energy necessary to reach the standard of three successive correct performances may have been a function of the massing of repetitions. It raises again the question of the relative value of distributed and massed repetitions in their influence on immediate recall, a question which the writer proposes to investigate experimentally in the near future.

Table IV gives the average differences in favor of the whole procedure for each of the mazes separately and for the two mazes combined, both in absolute amounts and in percentages. It will be observed that on one maze (PW IV) in one item, that of excess distance in the true path, the advantage appeared to be with the part method of learning. This is due to the fact that two rats (Rats 62 and 69, more particularly 62) which were in the whole group retraced excessively in learning this maze. Rat 69 was under all circumstances a poor learner. Rat 62 had, in a previous problem, been required to set up a habit in choice between paths

when coming out of a false alley which, when carried over into this problem, led him to retrace in the true path. When his record is excluded, the advantage for the whole procedure was without exception in any item and was greater in all items. Including the records of these two rats, the superiority of the whole procedure over the reversed repetitive part procedure in this test in terms of the criteria used was 44.1% in number of trials, 41.5% in amount of time, 43.1% in number of errors, 45.0% in number of units of excess distance travelled, and 44.5% in number of

TABLE IV

	PW IV		PW V		PW IV AND V	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials	16.15	32.4	22.7	55.7	19.42	44.1
Time	15' 22.55"	17.5	57' 44.28"	65.6	36' 33.41"	41.5
Errors:						
Retracing in true path	2.8	14.4	14.2	73.9	8.5	44.1
Blind forward	36.25	41.6	30.2	41.3	33.22	41.4
Blind backward	1.0	20.0	5.8	74.3	3.4	47.1
All kinds	40.0	36.0	50.4	50.2	45.2	43.1
Excess distance:						
In true path	-46.8	-4.8	1732.8	86.7	843.0	40.9
In false path	694.0	38.0	795.8	44.7	744.9	41.3
Both	647.2	23.2	2528.6	66.9	1587.9	45.0
Total distance	7010.3	31.3	11919.2	57.8	9464.7	44.5

units of total distance travelled. Excepting in number of errors made, the advantage for the whole compared with the reversed repetitive part method was considerably greater than the advantage for the whole compared with the pure part method.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the reversed repetitive part procedure in this study we find

1. That the whole procedure was superior, whatever be the criterion applied. In respect to number of units of total

distance travelled, which is the truest measure of energy expended, the advantage for the whole procedure was 44.5%.

2. That the advantage in favor of the whole procedure was greater when the whole procedure was compared with the reversed repetitive part procedure than when it was compared with the pure part procedure.
3. That in the reversed repetitive part procedure, learning three of the four parts of the maze constituted approximately $\frac{2}{3}$ and completing the learning by the addition of the fourth part approximately $\frac{1}{3}$ of the learning activity.
4. That, when all criteria are taken together, learning Parts II–III–IV in combination by the reversed repetitive part method did reduce somewhat the amount of energy required to master the whole by adding Part I, though there are many exceptions in different items both for the groups and for individual animals.
5. That in nearly every item and particularly in the number of units of total distance travelled, the amount of energy expended by the part groups of rats on learning three of the four parts of a maze exceeded that expended by the whole groups on learning the maze as a whole.
6. That the fact that less energy was required to add I to II–III–IV than was required to add II to III–IV may be a function of the distribution of repetitions, but this is in need of further investigation.

C. Comparison of whole with modified reversed repetitive part method

One pair of mazes and ten rats were used in testing the relative effectiveness of the whole and the modified reversed repetitive part procedures in learning. The first maze of the pair, PW VI, contained 351 units of true and 147 units of false pathway; the second, PW VII, contained 355 units of true and 155 units of false pathway. In learning Maze PW VI the rats numbered 60, 66, 68, 70 and 74 constituted the whole group, and those numbered 54, 64, 69, 73 and 76 constituted the part group. In learning Maze PW VII the groups were reversed.

The procedure differed from that employed in the reversed repetitive part method only in respect to the number of runs given to each of the part combinations for the rats of the parts groups. In the reversed repetitive part method the animals were required to master each part combination before being put to running the next; in this modified reversed repetitive part method they were given eight trials apiece on each of the part combinations (IV, III-IV, II-III-IV) and then, regardless of the amount of learning acquired, were set to running the maze as whole. One evening was devoted to each of the part combinations. The rats of the whole groups ran the whole maze in each trial, as usual, and were given 2 trials the first evening, 4 the second, and 6 the third. Then all rats were given 6 runs per evening until learning was complete. Ten evenings were spent on Maze PW VI and nine evenings on Maze PW VII.

The behavior of the rats of the part groups in learning Part IV and of the whole groups in learning the whole maze was similar to their behavior in learning the corresponding portions of Mazes PW IV and PW V. In the eight runs given each rat of the part groups on each part combination, five rats (Rats 54, 64, 60, 68 and 70) succeeded in making three successive correct runs on Part IV, three rats (Rats 54, 69 and 70) on Parts III-IV, and none on Parts II-III-IV. That is, according to the standard adopted, they mastered those parts. With every transfer from one part combination to another the new learning problem was attacked eagerly. Upon reaching the point of transition between the new and the old, however, there was much less tendency to hesitation than there had been in the preceding pair of mazes. On the contrary, in most of the runs the animals made that turn at the transition point just as they made any other turn in the maze, but they did not then run the already-practiced portion of the maze as if it were familiar. In six of the thirty times the transfer was made from practiced to unpracticed parts the runs were without error in the practiced portions (Rats 54, 64 and 73 from Part IV to III-IV, Rat 69 from Part III-IV to II-III-IV, and Rat 64 from Part II-III-IV to the whole), but in only one instance (Rat 64 on the whole) was this accuracy consistently maintained

TABLE V

		PW VI		PW VII	
Group of rats		Part	Whole	Part	Whole
Number of trials	Parts	<u>48</u>		<u>48</u>	
		4		4	
	Whole	19.6		14.6	
	Both	31.6	34	26.6	18.2
Time	P	20' 50.74''		19' 35.56''	
	W	30' 34.56''		20' 16.80''	
	B	51' 25.30''	46' 35.36''	39' 52.36''	31' 58.66''
Number of errors:					
Retracing in true path	P	4.8		2.8	
	W	5.6		3.0	
	B	10.4	6.4	5.8	8.2
Blind forward	P	27.4		32.4	
	W	33.8		19.6	
	B	61.2	52.2	52.0	36.8
Blind backward	P	1.4		1.4	
	W	1.0		1.0	
	B	2.4	3.0	2.4	2.2
All kinds	P	33.6		36.6	
	W	40.4		23.6	
	B	74.0	61.6	60.2	47.2
Number of units of excess distance:					
In true path	P	347.0		127.2	
	W	323.6		71.2	
	B	670.6	189.6	198.4	393.0
In false path	P	567.6		728.0	
	W	693.2		327.2	
	B	1260.8	1003.2	1055.2	857.6
Total	P	914.6		855.2	
	W	1016.8		398.4	
	B	1931.4	1192.8	1253.6	1250.6
Number of units of total distance traveled	P	5126.6		5115.2	
	W	7896.4		5581.5	
	B	13023.0	13126.8	10696.7	7711.6
Rats used		54, 64, 69, 73, 76	60, 66, 68, 70, 74	60, 66, 68, 70, 74	54, 64, 69, 73, 76

through more than two runs. The errors, though, were neither numerous nor serious in character and were quickly dropped. The fact that the amount in trials, time, errors, and total distance, excepting for one item in one maze (excess distance in the true path in PW VI), was considerably less for the rats of the part group after they were set to running the maze as a whole than for the rats of the whole group indicates that the practice on the part combinations contributed in some measure to the learning of the mazes.

Table V gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance in the true pathway and in the false pathway, and number of units of total distance travelled. Examination of these data shows that in general the whole groups were superior to the part groups in learning the mazes, but with exceptions in the number of trials and the number of errors of the blind-backward type in Maze PW VI and in the number of errors of the retracing type and the number of units of excess distance travelled in the true path in Maze PW VII. In particular items this superiority in learning by the whole method was true for individual animals, too, though with a great many exceptions. In the results obtained from eight rats there were differences in favor of the part method in some of the items.

Rat 54 in errors of the blind-backward type.

Rat 60 in trials, time, errors of each type, total errors, excess distance in the true path, and total distance travelled.

Rat 68 in trials, time, errors of the retracing and blind-forward types, total errors, excess distance in the true path, and total excess distance.

Rat 69 in trials, time, errors of the blind-backward type, and total errors.

Rat 70 in trials, time, errors of each type, total errors, excess distance in the true and in the false pathway, and total excess distance.

Rat 73 in errors of the blind-backward type.

Rat 74 in excess distance in the true and in the false pathway, total excess distance, and total distance travelled.

Rat 76 in errors of the blind-backward type.

Rats 68 and 70, two of the best learners under normal conditions, were ill a part of the time while learning Maze PW VI by the whole procedure and so were not at their best. This may account in some measure for the number of items in which the part method appeared to have been better for them than the whole method, but when we apply the criterion which is the best

TABLE VI

	PW VI		PW VII		PW VI AND VII	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials	-2.4	-7.5	8.4	31.6	3.0	12.05
Time	4' 49.9''	9.3	7' 53.7''	19.8	6' 21.8''	14.5
Errors:						
Retracing in true path....	4.0	38.4	-2.4	-41.3	.8	-1.45
Blind forward	9.0	14.7	15.2	29.2	12.1	21.9
Blind backward	-.6	-25.0	.2	8.3	-.2	-8.35
All kinds	12.4	16.7	13.0	21.5	12.7	19.1
Excess distance:						
In true path	481.0	71.7	-194.6	-98.0	143.2	-13.15
In false path	257.6	20.4	197.6	18.7	227.6	19.55
Both	738.6	38.2	3.0	.23	370.8	19.21
Total distance	-103.8	-0.7	2985.1	27.9	1440.7	13.6

measure of energy required for learning, namely, the total distance travelled, the whole procedure was the superior one for them. This was not true for Rats 60 and 74. The part method employed proved to be better for them in respect to total distance travelled. Though the exceptions for the mazes taken separately and for the animals taken separately were numerous, when averages are computed for both mazes and for all rats, the advantage of the whole over the part procedure is obvious. Table VI gives the average differences in favor of the whole method for each of the mazes separately and for the two mazes combined both in abso-

lute amounts and in percentages. It will be observed that for some items the part procedure had the advantage—for errors of the retracing type and for number of units of excess distance in the true path in PW VII, for errors of the blind-backward type in the Maze PW VI, and for all three items in the average of the two mazes taken together. When all kinds of errors are totalled and excess distance in both the true and the false pathway are considered the advantage was still with the whole procedure. Expressed in terms of the criteria employed the superiority of the whole over the modified reversed repetitive part method was 12.05% in number of trials, 14.5% in amount of time, 19.1% in number of errors, 19.21% in number of units of excess distance travelled, and 13.6% in number of units of total distance travelled.

It is again of interest to note the relative amount of learning effort given to the learning of the parts and to learning the whole by the part groups. The results obtained from the mazes show that for all of the part combinations taken together, for each of them separately, and for the learning of the whole by the addition of Part I, the proportions were:

	IV	III-IV	II-III-IV	PARTS	WHOLE
Trials.....	6.9%	13.7%	20.6%	41.2%	58.8%
Time.....	6.7	15.6	21.8	44.1	55.9
Errors.....	8.3	20.0	23.0	51.3	48.7
Excess distance.....	7.1	25.3	23.2	55.6	44.4
Total distance.....	7.2	15.3	20.8	43.3	56.7

With this method, up to the point where Part II, III, and IV were combined, the proportion of energy expended by the rats of the part groups was approximately $\frac{1}{2}$ of the total amount of energy required for complete learning.

Compared with the reversed repetitive part procedure the modified reversed repetitive part procedure showed certain very marked differences. In learning by the latter method more animals were able to run from a new into an already practiced section of the maze without making errors in the first runs in the

latter section. The errors made under these conditions were less serious in character and were more quickly dropped. The whole groups showed less superiority in the items in which they were superior at all, and more items in which they were not superior to the part groups. The relative amount of learning effort given by the part groups to the parts was less and that given to the whole was more. There was less consistency in results for the mazes taken singly, for the animals taken singly, and for the mazes taken together, and for the animals taken by groups. The absolute amounts and percentages of advantage in the various items were less for the whole group. In other words, in all particulars the modified reversed repetitive part method more closely approached the whole method in effectiveness for learning than did the reversed repetitive part method.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the modified reversed repetitive part procedure in this study we find—

1. That the whole procedure was superior, whatever be the criterion applied. In respect to the number of units of total distance travelled the advantage for the whole procedure was 13.6%.
2. That the advantage in favor of the whole procedure was less when the whole procedure was compared with the modified reversed repetitive part method than when it was compared with either the reversed repetitive part method or the pure part method.
3. That in the modified reversed repetitive part procedure, practice amounting to 8 trials on each of the part combinations (IV, III-IV, II-III-IV) of the maze constituted approximately $\frac{1}{2}$ and completing the learning by the addition of the fourth part (Part I) approximately $\frac{1}{2}$ of the learning activity.
4. That practice amounting to 8 trials on each of the part combinations reduced the amount of energy required to master the whole by the addition of Part I. There was only one exception (number of units of excess distance in the true path in Maze PW VI).

5. That the modified reversed repetitive part method compared more favorably with the whole method in effectiveness in learning than either the reversed repetitive part method or the pure part method.

D. Comparison of whole with progressive part procedure

One pair of mazes and ten rats were used to test the relative effectiveness of the whole and the progressive part procedures in learning. The first maze of the pair, PW VIII, contained 404 units of true and 152 units of false pathway; the second, PW IX, contained 395 units of true and 150 units of false pathway. In learning Maze PW VIII the rats numbered 60, 66, 68, 70, and 74 constituted the whole group and those numbered 54, 64, 73, 75, and 76 constituted the part group. In learning Maze PW IX the groups were reversed.

For each maze the procedure was as follows: each rat of the part group was run in Part I of the maze 8 times per evening until three successive correct runs had been made. Then he was transferred to Part II and run on that part 8 times per evening until the same standard of success had been attained. Then he was required to run parts I and II together 4 times per evening until he had made three consecutive correct runs. This was followed by running Part III 8 times per evening until it was learned, then adding it to the I-II combination and running this combination three times per evening (two times every third evening) until it was learned. Likewise Part IV was learned and added to the I-II-III combination and two trials were given on the whole each evening until all the rats were ready to run the whole. Then six trials were given each evening until the maze was mastered. For the rats of the part groups this procedure necessitated the mastery of six separate part combinations (I, II, I-II, III, I-II-III, and IV) before the maze was finally mastered as a whole. It resembles the pure part method in that each part of the maze was learned separately, but differs from the pure part method in the fact that each part, after it had been learned, immediately became a functional part of a larger combination which grew progressively more complex as the parts were added to it. This

method resembles the reversed repetitive part method in that the learning problem grew progressively more complex, but differs from it in that the learning of the new and the review of the already-learned parts of the maze were not combined in the same learning act, that the learning material of the final learning act included only that which had already been learned, and that the maze was learned from beginning to end rather than from end to beginning. Each of the rats of the whole group ran the entire maze two times per evening. On Maze PW VIII the number of trials was increased to six per evening when all of the rats of the part group were ready to be put upon the whole, but this was not possible on Maze PW IX because all excepting one of the rats of the whole group had mastered the maze before some in the part group had completed the learning of the part combinations. Eighteen evenings were spent on Maze PW VIII and twenty-five on Maze PW IX. The general procedure was that previously described (Section II D).

The learning of the parts singly by the rats of the part groups and of the whole maze by the rats of the whole groups proceeded in the way described for similar learning on previous mazes. When the rats of the part groups were transferred from single parts to combinations formed of single parts already learned, that is, from Part II to I-II, from III to I-II-III, and from IV to the whole, their behavior was different. Just as in learning Mazes PW II and PW III by the pure part procedure, they stopped at the transitions between parts, often for many seconds, trying to find their way through the old path into the food-box. Sometimes they retraced from the point of transition, though more often they proceeded into the next section of the maze. But in all cases there was little evidence of recognition of the path as a familiar one. In no instance was the first run after transference from a learned part to a combination of learned parts free from hesitations, in only three out of the thirty instances was it free from actual error, and none of these errorless first runs was followed immediately by a second run without error. The number of errors in these runs varied from 0 to 6, the average for all rats on both mazes being 2. Except for hesitations at

transition points, and a greater amount of retracing, the first few runs on combinations of already-learned parts for most rats were in character very much like the first runs of the same rats on any new maze. Using the criteria of amount of time, number of trials, number of errors, number of units of excess distance travelled, and number of units of total distance travelled, a comparison of the amount of effort expended upon the different acts shows that learning to combine the already-mastered parts required from 2 to 4 times as much energy as learning the parts singly. The amounts varied according to the criterion employed. The percentages obtained were:

	I	II	I-II	III	I-II-III	IV	PARTS	WHOLE
Trials.....	3.5%	5.3%	10.9%	5.6%	32.6%	4.9%	62.8%	37.2%
Time.....	4.2	5.1	10.2	6.3	32.3	4.8	62.9	37.1
Errors.....	7.1	10.8	9.2	9.9	27.7	7.6	72.3	27.7
Excess distance.....	7.0	9.6	9.3	10.9	25.9	8.5	71.2	28.8
Total distance.....	4.4	5.5	10.5	6.1	32.1	5.5	64.1	35.9

When the proportions of energy spent on learning the parts separately and on learning the parts combined are computed, the results show that considerably more than $\frac{2}{3}$ of the total energy required for learning was devoted to the act of combining already-learned sections and less than $\frac{1}{3}$ to the original mastery of the parts themselves. The actual percentages were

	PARTS SINGLY	PARTS COMBINED
Trials.....	19.3%	80.7%
Time.....	20.4	79.6
Errors.....	35.4	64.6
Excess distance.....	36.0	64.0
Total distance.....	21.5	78.5

That some learning was acquired and retained as a result of learning the parts separately and combining them progressively is evident from the fact that the amount in time, errors, trials, excess distance and total distance was in general less for the part groups in running the whole maze than for the whole groups.

TABLE VII

		PW VIII		PW IX	
Group of rats.....		Part	Whole	Part	Whole
Trials.....	Parts	<u>89.6</u>		<u>121.8</u>	
		4		4	
	Whole	7.6		23.0	
	Both	30.0	25.2	53.45	20
Time.....	P	35' 23.64''		48' 49.32''	
	W	12' 36.10''		37' 8.54''	
	B	47' 59.74''	38' 40.5''	85' 57.86''	31' 52.9''
Number of errors:					
Retracing in true path.....	P	7.2		6.0	
	W	1.6		4.8	
	B	8.8	7.0	10.8	9.4
Blind forward.....	P	46.6		43.0	
	W	9.6		20.8	
	B	56.2	40.8	63.8	44.8
Blind backward.....	P	1.4		3.2	
	W	1.6		1.6	
	B	3.0	3.6	4.8	6.6
All kinds.....	P	55.2		52.2	
	W	12.8		27.2	
	B	68.0	51.4	79.4	60.8
Number of units of excess distance:					
In true path.....	P	275.2		226.4	
	W	102.8		220.8	
	B	378.0	288.8	447.2	493.6
In false path.....	P	968.8		845.6	
	W	216.0		394.0	
	B	1184.8	870.8	1239.6	974.4
Total.....	P	1244.0		1072.0	
	W	318.8		614.8	
	B	1562.8	1159.6	1686.8	1468.0
Number of units of total distance traveled.....	P	10293.6		13099.75	
	W	3389.2		9699.8	
	B	13682.8	11340.4	22799.55	9368.0
Rats used.....		54, 64, 73, 75, 76	60, 66, 68, 70, 74	60, 66, 68, 70, 74	54, 64, 73, 75, 76

Table VII gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance taken in the true and in the false pathway, and number of units of total distance travelled. Trials were computed, errors classified and counted and units of total distance determined as in the part methods previously used. Examination of these data shows that in every particular, excepting in errors of the blind-backward type in both mazes and units of excess distance in the true path in Maze PW IX, the whole groups were superior to the part groups in learning the mazes. With some exceptions this was true for individuals as well as for groups. In the results obtained from Rat 73, the part procedure proved to be equal or superior to the whole procedure in all items. For Rat 76 the part procedure proved to be superior in six of the ten items compared, but the whole procedure excelled in respect to time, blinds taken while running in a forward direction, excess distance in the false pathway, and total distance travelled. Rat 54 retraced more, Rats 60, 64, and 70 took more excess distance in the true pathway, Rat 68 made more errors of the blind-backward type, and Rat 75 retraced more and made more errors of the blind-backward type in learning by the whole method than in learning by the progressive part method. Nearly all of these exceptions are due to the peculiar behavior of the rats of the whole group at one particular point in Maze PW IX. For some reason which the writer has been unable to determine certainly, in their early runs most of the animals of that group, on reaching the fourth alley of the seventh pathway, turned back and retraced a large part of the section already run. In some runs they repeated this behavior several times before finally proceeding into the next alley and completing the run. This, of course, resulted in an accumulation of excess distance and of errors of the retracing and blind-backward types, and detracted from the superiority of the whole procedure for that maze. In spite of this peculiar reaction on the part of that group of animals, when averages were taken for all rats and the part and whole groups were compared, the whole procedure proved to be the superior one for Maze PW IX in all

excepting two items—errors of the blind-backward type and excess distance in the true path. In fact, in three items—number of trials, amount of time, and number of units of total distance—the rats of the part groups before they were set to running the maze as a whole had already reached averages greater than the averages for the rats of the whole group in learning the mazes as wholes. The averages are:

	PART GROUPS ON PARTS	WHOLE GROUPS ON WHOLE
Trials	26.425	22.6
Time	42' 6.47"	35' 16.7"
Errors	53.7	56.1
Excess distance	1158.0	1313.8
Total distance	11696.7	10354.2

When both mazes are taken together, the whole method was superior in all items excepting errors of the blind-backward type, and the difference in favor of the progressive part method in that item was small.

Table VIII gives the average differences in favor of the whole procedure for each of the mazes separately and for the two mazes combined both in absolute amounts and in percentages. It will be observed that by whatever criterion the two methods are compared there was an advantage for the whole method—39.1% in number of trials, 41.15% in amount of time, 23.9% in number of errors, 19.3% in number of units of excess distance, and 38.0% in number of units of total distance travelled.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the progressive part procedure in this study we find

1. That the whole procedure was superior, whatever be the criterion applied. In respect to number of units of total distance travelled, which is the best measure of energy spent, the advantage for the whole procedure was 38.0%.
2. That the advantage in favor of the whole procedure was greater when it was compared with the progressive part procedure than when it was compared with the pure part

and modified reversed repetitive part procedures, and less when it was compared with the reversed repetitive part procedure.

3. That in the progressive part procedure, the learning acts required before the maze was run as a whole constituted more than $\frac{2}{3}$, and completing the learning by running the maze as a whole less than $\frac{1}{3}$ of the learning activity.
4. That learning the parts and part combinations by the progressive part method did reduce the amount of energy required to finally master the maze as a whole.

TABLE VIII

	PW VIII		PW IX		PW VIII AND IX	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials.....	4.8	16.0	33.45	62.2	19.125	39.1
Time.....	9' 19.24"	19.4	54' 4.96"	62.9	31' 42.1"	41.15
Errors:						
Retracing in true path..	1.8	20.4	1.4	13.0	1.6	16.7
Blind forward.....	15.4	27.4	19.0	29.7	17.2	28.55
Blind backward.....	-.6	-20.0	-1.8	-37.5	-1.2	-28.75
All kinds.....	16.6	24.4	18.6	23.4	17.6	23.9
Excess distance:						
In true path.....	89.2	23.6	-46.4	-10.3	21.4	6.6
In false path.....	314.0	26.5	265.2	21.3	289.6	23.9
Both.....	403.2	25.7	218.8	12.9	311.0	19.3
Total distance.....	2342.4	17.1	13431.5	58.9	7886.9	38.0

5. That in number of trials taken, amount of time required and units of total distance travelled, the amount of energy expended by the rats of the part groups on learning the parts and part combinations, exclusive of the combination I-II-III-IV, exceeded that expended by the rats of the whole groups on learning the maze as a whole. In respect to errors and excess distance this was not true.

E. Comparison of whole with direct repetitive part procedure

One pair of mazes and 11 rats were used to compare the relative effectiveness of the whole and the direct repetitive part proce-

dures in learning. The first maze, PW X, contained 369 units of true and 152 units of false pathway; the second, PW XI, contained 376 units of true and 154 units of false pathway. In learning the first maze the rats numbered 60, 66, 68, 70, 74 and 78 constituted the "whole" group and those numbered 54, 64, 73, 75 and 79 constituted the "part" group. In learning the second maze the groups were reversed.

For each maze the procedure was as follows: each rat of the part group ran in Part I of the maze eight times per evening until three successive correct runs had been made. Then he was again put into Part I and required to run Parts I and II together four times per evening until three successive correct runs had been made. Next he was required to run Parts I, II and III in combination three times per evening (two times each third evening) until three successive correct runs had been made. Finally he was required to run the whole maze, that is, Parts I, II, III and IV in combination. Each of the rats of the whole group ran the entire maze two times per evening until all of the rats of the part group were ready to run the maze as a whole, when the number of runs was increased for all rats that had not yet completed the learning. Seventeen evenings were spent on Maze PW X and twenty-two evenings on Maze PW XI. The general procedure employed was that described in Section II D above.

This procedure, it will be observed, is similar to that employed in the reversed repetitive part method in the respect that with each transfer to a new combination of parts the animal was confronted with a new problem which included both the review of an already learned section and the mastery of a new one. The two procedures differ, however, in the order of attack. In the reversed repetitive part method the animal ran first a new section of the maze and then one or more already learned sections. In this method the order was reversed, the animal after each transfer running from an already learned section into a new one.

The learning of Part I by the animals of the part group and of the maze as a whole by the animals of the whole group proceeded in the way described for the learning corresponding units in pre-

TABLE IX

Group of rats.....	PW X		PW XI	
	Part	Whole	Part	Whole
Number of trials.....	P	90.6	92.33	
	W	$\frac{4}{34.5}$	4	
	B	57.15	34.16 57.24	50.8
Time.....	P	38' 42.76"	36' 4.01"	
	W	53' 52.14"	55' 30.72"	
	B	1 hr. 32' 34.90"	1 hr. 31' 34.73"	1 hr. 19' 48.7"
Number of errors:				
Retracing in true path.....	P	12.0	7.3	
	W	9.2	6.7	
	B	21.2	14.0	7.4
Blind forward.....	P	35.6	35.2	
	W	39.2	36.3	
	B	74.8	71.5	83.0
Blind backward.....	P	6.0	4.2	
	W	2.0	2.8	
	B	8.0	7.0	3.2
All kinds.....	P	53.6	46.7	
	W	50.4	45.8	
	B	104.0	92.5	93.6

Number of units of excess distance:					
{	P	495.2			446.0
	W	377.6			432.7
	B	872.8	1028.0		878.7
In true path.....					234.4
{	P	878.8			836.0
	W	716.0			826.7
	B	1594.8	1110.3		1662.7
In false path.....					2378.8
{	P	1374.0			1282.0
	W	1093.6			1259.4
	B	2467.6	2138.3		2541.4
Total.....					2613.2
{	P	9731.8			9961.02
	W	13824.1			14103.56
	B	23555.9	14558.8		24064.58
Number of units of total distance traveled					21714.0
Rats used.....		54, 64, 73, 75, 79	60, 66, 68, 70, 74, 78	60, 66, 68, 70, 74, 78,	54, 64, 73, 75, 79

ceding problems. When the rats of the part group had completed the learning of Part I and were put upon Parts I and II in combination, in the first few runs they stopped at the point of transition between the two sections, pushed and pawed at the panel blocking the path which had previously led into the food box, and sometimes retraced into the latter paths of Part I, though more often they proceeded into Part II after a brief hesitation. These hesitations, however, were quickly dropped. With the addition of Part III and Part IV in turn there was the same tendency to hesitate at transition points and also the same tendency after only a little practice to proceed smoothly from one section to the next. The behavior of the animals in running the already learned portions was in each case the same as their behavior in running any maze with which they were familiar, and the newly added sections were learned just as any other maze or part of a maze. There was little disturbance in the running of the already learned portions from having added the new increment from time to time.

Table IX gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance taken in the true and in the false pathway, and number of units of total distance travelled. Examination of these data shows that with exceptions in a few items the whole groups were superior to the parts groups in learning the mazes. In PW X the number of errors of the blind-backward type and the number of units of excess distance in the true path were greater for the whole group; in PW XI the number of errors of the blind-forward type, the total number of errors, the number of units of excess distance in the false pathway, and the total number of units of excess distance were greater for the whole group than for the part group. When, however, the averages of results from both mazes are taken, the part group had an advantage in only one item, the number of units of excess distance taken in the false pathway, and this advantage was small. This superiority in learning by the whole method was in general true for the individual animals but with some interesting exceptions. Rats Number 54 and 73, both of

which learned Maze PW X by the part method, showed differences in favor of the part procedure in respect to number of trials, amount of time, number of errors of the blind-forward type, number of units of excess distance in the false pathway, and number of units of total distance travelled. Other differences in favor of the part method were

Rat 60—number of errors of the blind-forward type and of the blind-backward type, and excess distance in the false pathway.

Rat 64—excess distance in the false pathway.

Rat 68—number of errors of each type and number of units of excess distance in both the false and the true pathways.

Rat 78—number of errors of the retracing-true and blind-backward types and excess distance in the true pathway.

Rat 79—number of trials and number of errors of the blind-forward type.

When we apply the criterion which is the best measure of energy required for learning, namely, the number of units of total distance travelled, the whole procedure proved to be the superior one for all rats excepting Number 54 and Number 73. In spite of these exceptions for animals taken separately, when averages are computed for both mazes and for all rats the advantage was in favor of the whole method. Table X gives the average differences in favor of the whole method for each of the mazes separately and for the two mazes taken together, both in absolute amounts and in percentages. It will be observed that for some items the part procedure had the advantage—in Maze PW X for errors of the blind-backward type and units of excess distance in the true path; in Maze PW XI for errors of the blind-backward type, total errors and total units of excess distance; but in the average of the two mazes taken together only for units of excess distance in the false pathway. Expressed in terms of the criteria employed, the superiority of the whole procedure over the direct repetitive part procedure was 26.1% in number of trials, 22.7% in amount of time, 11.6% in number of errors, 5.25% in units of excess distance, and 23.9% in units of total distance travelled. These percentages were in general less than the percentages of advantage for the whole procedure when compared with other

part procedures with the exception of the modified reversed repetitive part procedure in which only partial learning of each part combination was required before the next increment was added. In other words, the direct repetitive part procedure compared more favorably with the whole procedure than any other included in this study excepting the modified reversed repetitive part procedure.

It is again of interest to note the relative amount of learning effort given by the part groups to the learning of the parts in com-

TABLE X

	PW X		PW XI		PW X AND XI	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials.....	23.49	41.1	6.44	11.2	14.97	26.1
Time.....	30' 4.6"	32.5	11' 46.0"	12.8	20' 55.3"	22.7
Errors:						
Retracing in true path...	6.2	29.2	6.6	47.1	6.4	38.1
Blind forward.....	21.0	28.0	-11.5	-16.0	4.75	6.0
Blind backward.....	-1.8	-22.5	3.8	54.3	1.0	15.9
All kinds.....	25.4	24.4	-1.1	-1.2	12.15	11.6
Excess distance:						
In true path.....	-155.2	-17.8	644.3	74.4	244.5	28.3
In false path.....	484.5	30.4	-716.1	-43.0	-115.8	-6.3
Both.....	329.3	13.3	-71.8	-2.8	128.75	5.25
Total distance.....	8997.7	38.1	2350.6	9.7	5673.8	23.9

bination through Parts I, II and III and to the learning of the whole by the addition of Part IV. The results obtained from the two mazes show that for each of the part combinations taken separately, for all of them taken together, and for the mastery of the whole after Part IV was added, the percentages were

	I	I-II	I-II-III	PARTS	WHOLE
Trials.....	3.0%	14.0%	23.0%	40.0%	60.0%
Time.....	3.7	15.0	21.8	40.5	59.5
Errors.....	5.8	22.5	22.7	51.0	49.0
Excess distance.....	5.3	25.4	22.3	53.0	47.0
Total distance.....	3.9	15.9	21.5	41.3	58.7

With this method, up to the point where the part combinations (exclusive of the final combination making the whole) had been mastered, the proportion of energy expended by the rats of the part groups was a little less than $\frac{1}{2}$ of the total amount of energy required for complete learning.

Compared with the reversed repetitive part procedure the direct repetitive part procedure showed certain very marked advantages. In learning by the latter method the hesitations and retracing errors at points of transitions between parts immediately after a new increment had been added were less serious and were more quickly dropped. As was to be expected, the addition of the new increment had no effect on the running of the part already learned and at no time did an animal behave in an already learned section as if he were not familiar with it. Not nearly so large a proportion of the total energy expended was required to master the first three of the four parts learned and in no item was more energy used by the rats of the part groups in mastering these first three parts than was used by the rats of the whole groups in learning the maze as a whole. As before, that there was some learning retained from having learned the first three sections by this direct cumulative method is indicated by the fact that the amount in trials, time, errors, excess distance and total distance was in general less for the rats of the part groups after they were set to running the maze as a whole than for the rats of the whole groups.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure in this study, we find

1. That the whole procedure was superior, whatever the criterion applied. In respect to number of units of total distance travelled the advantage for the whole procedure was 23.9%.
2. That the advantage for the whole procedure was somewhat greater when the whole procedure was compared with the direct repetitive part procedure than when it was compared with the modified reversed repetitive part proce-

- ture; but less when the whole procedure was compared with the direct repetitive part procedure than when it was compared with the reversed repetitive part procedure, the progressive part procedure, or the pure part procedure.
3. That in the direct repetitive part procedure, learning three of the four parts of the maze constituted approximately $\frac{1}{2}$ and completing the learning by the addition of the fourth part approximately $\frac{1}{2}$ of the learning activity.
 4. That, when all criteria are taken together, learning Parts I-II-III in combination by the direct repetitive part method did reduce somewhat the amount of energy required to master the whole after Part V had been added.
 5. That the direct repetitive part method compared more favorably with the whole method in effectiveness in learning than any other method tested excepting the modified reversed repetitive part method.

IV. CONCLUSION

From the results obtained in the experiments described in the earlier sections of this paper we feel justified in concluding that, for rats learning maze patterns, the whole method is superior to either the pure part method, the reversed repetitive part method, the modified reversed repetitive part method, the progressive part method, or the direct repetitive part method.

In every test made the whole procedure proved to be superior in respect to all the criteria employed. In respect to number of units of total distance travelled, which is the truest measure of energy expended, the advantage of the whole method amounted to 26.7% in comparison with the pure part method, 44.5% in comparison with the reversed repetitive part method, 13.6% in comparison with the modified reversed repetitive part method, 38.0% in comparison with the progressive part method, and 23.9% in comparison with the direct repetitive part method. The advantage of the whole method in respect to each of the criteria when compared with the part methods was

	MOD. REV. REP. PART	DIR. REP. PART	PURE PART	PROG. PART	REV. REP. PART
Trials.....	12.05%	26.1%	25.8%	39.1%	44.1%
Time.....	14.50	22.7	18.0	41.15	41.5
Errors.....	19.10	11.6	27.8	23.9	43.1
Excess distance.....	19.21	5.2	31.1	19.3	45.0
Total distance.....	13.6	23.9	26.7	38.0	44.5

Of the methods of learning tested, the order of effectiveness from greatest to least was whole, modified reversed repetitive part, direct repetitive part, pure part, progressive part and reversed repetitive part. Whenever the total pattern was broken into parts and then combined again into the whole, the process of learning required the expenditure of more total energy than when the pattern was kept unbroken throughout the learning period. It is evident that in these tests learning the parts and part combinations first did not interfere with learning the mazes as wholes finally, for the rats of the part groups were able, after the parts had been mastered, to master the whole with less effort than the rats of the whole groups. In other words, there was an actual saving in the amount of energy required to master each maze as a whole by having first practiced the parts separately. The results on the reversed repetitive part and the modified reversed repetitive part methods indicate that the amount of this saving was somewhat greater when the parts were really mastered than when they were given only a limited amount of practice. The table below gives the percentages of saving for each of these two methods.

	REV. REP. PART METHOD	MOD. REV. REP. PART METHOD
Trials.....	44.1%	34.5%
Time.....	45.8	35.2
Errors.....	44.6	41.1
Excess distance.....	31.8	42.0
Total distance.....	42.0	35.3

Notwithstanding the fact that energy was saved in learning the whole by having first learned the parts and that more was saved

when the parts were mastered than when they were only partially learned, there was actual waste of energy in learning by the part methods in comparison with the whole method when total energy required is considered. The saving on the final learning of the whole was much less than the energy expended on the parts. All this was true in spite of the fact that whenever in the procedure an advantage had to be given to one group or to the other, it was given to the part group. The part group had an advantage in the counting of time. The time spent in the early alleys of each part and part combination was counted out for them while only the time spent in the alleys of the first part was counted out for the rats of the whole groups. Another possible item in their favor was the greater number of runs given them per evening. If, as seems probable, the amount of energy required to make the standard score is in any measure a function of the massing of effort, the rats of the part groups had the advantage in this respect. As soon as all of them were ready for the whole the number of runs per evening was increased, so that they probably reached the score relatively more quickly than they would have done if their practice on the whole maze had been as distributed as in the case of the rats of the whole groups. This means that the whole groups were required to acquire a pattern that, after the lapse of considerable time, would probably be better retained than in the case of the part groups. Despite these facts, the whole method proved to be the superior one in comparison with all part methods tested for every maze and for every rat excepting one rat on one pair of mazes (Rat 73 on Mazes PW VIII and PW IX).

This superiority of the whole procedure was demonstrated again when the data were tabulated and computed in quite different ways. Comparing the average total distance travelled by the rats of the part groups with the average total distance travelled by those of the whole groups in learning each of the mazes, the results shown in Table XI were obtained. Again the relative effectiveness of a run on four parts as compared with a run on the whole was determined by taking the amount saved

TABLE XI

MAZES	RATS OF WHOLE GROUPS	RATS OF PART GROUPS			PER CENT AVERAGE TOTAL DISTANCE RUN BY A RAT OF THE PART GROUP IS OF THAT RUN BY A RAT OF THE WHOLE GROUP $\frac{x}{y}$
	Average total distance y	Average total distance on parts	Average total distance on whole	Average total distance x	
Last three correct runs on parts included					
PW VI and VII.....	10419.20	5120.90	6738.95	11859.85	113.8%
PW X and XI.....	18136.40	9846.41	13963.83	23810.24	131.2%
PW II and III.....	9099.10	4560.44	8032.52	12592.96	138.3%
PW VIII and IX.....	10354.20	11696.68	6544.50	18241.18	176.1%
PW IV and V.....	12029.70	14525.95	6968.50	21494.45	178.6%
Last three correct runs on parts excluded					
PW X and XI.....	18136.40	8270.16	13963.83	22233.99	122.4%
PW II and III.....	9099.10	3454.94	8032.52	11487.46	126.2%
PW VIII and IX.....	10354.20	9000.03	6544.50	15544.53	150.1%
PW IV and V.....	12029.70	12686.65	6968.50	19655.15	163.3%

TABLE XII

	WHOLE METHOD	PW VI AND VII	PW X AND XI	PW II AND III	PW VIII AND IX	PW IV AND V
		Modified reversed repetitive part method	Direct repetitive part method	Pure part method	Progressive part method	Reversed repetitive part method
Last three correct runs on parts included						
Trials.....	100%	75%	34%	19%	27%	37%
Time.....	100	68	44	46	24	39
Errors.....	100	63	75	50	67	37
Excess distance.....	100	58	90	43	73	25
Total distance.....	100	71	42	24	32	34
Last three correct runs on parts excluded						
Trials.....	100	75	50	30	42	39
Time.....	100	68	51	67	33	45
Errors.....	100	63	75	50	67	37
Excess distance.....	100	58	90	43	73	25
Total distance.....	100	71	49	33	41	39

for the rats of the part groups in learning each maze as a whole due to first having mastered the parts, and dividing that amount by the effort required to learn the parts. This fraction was expressed as per cent. The results obtained are given in Table XII.

It is clear that whatever criterion be used, whether or not the last three correct runs required as evidence of mastery of each part or part combination be included, whether the comparison be made in terms of per cent of advantage for the whole procedure or in terms of per cent of relative effectiveness of a run on four parts as compared with a run on the whole, there proved to be a decided advantage in favor of the whole procedure when compared with any of the part procedures employed in this study.

In all tests there were some items for some rats in which the part procedure seemed to have the advantage. These were most numerous in the modified reversed repetitive part method which most closely approached the whole in degree of effectiveness, and least numerous in the reversed repetitive part method which was farthest removed from the whole in degree of effectiveness. But when all rats and both mazes in each test are taken together, however the data are computed, there was unmistakable superiority in learning by the whole method and we are forced to the conclusion that for this type of learning the whole procedure is better than any of the part procedures compared with it.

A second conclusion derived from the results obtained in these experiments is that with trained animals there is no evidence of progressively increasing facility in mastering maze patterns of comparable difficulty. When all of the other variables have been eliminated by means of thorough training of animals and of control of objective conditions, and when the problem is confined to that of learning the specific maze pattern involved, the amount of energy required for learning depends on the nature of the problem itself and on the relatively constant individual differences among the animals, not upon the amount of practice they have been given previously. In the two methods in which each part was learned separately before being attacked in combination with

other parts, the order of difficulty of learning did not show progressive decrease. In Mazes PW II and PW III, learned by the pure part procedure, the order was II, IV, I, III; in Mazes PW VIII and PW IX learned by the progressive part procedure, it was I, IV, II, III.

A third conclusion reached is that the learning of one maze or part of a maze, when it is unique in character, does not affect either positively or negatively the learning of later mazes. This was demonstrated by the fact that there were on the part of the rats no consistently increasing readiness or reluctance to attack new problems, no significant differences in energy required to learn successive mazes, and no changes in general behavior from one problem to another. In all tests, parts of mazes or mazes that were learned as wholes were mastered in very much the same way.

A fourth conclusion is that the problem of the relative value of distributed and massed repetitions in immediate recall is in pressing need of further investigation. There is some evidence in the test of the reversed repetitive part method that the decrease in number of runs per evening as the part combinations became larger resulted in disproportionate increase in the amount of energy required for reaching the score. It has not been the purpose of this study to investigate the problem of distribution of repetitions, hence no conclusion can be derived, but the results suggest that massing of effort may be a factor influencing efficiency in learning of this type.

The results obtained and the conclusions reached are in harmony with the findings of all earlier investigators and of many of the recent investigators using rote and meaningful material and human subjects. They are in disagreement with the findings of those who have used motor learning material and with the findings of Pechstein (18) who used animal subjects. Pechstein ranked the learning methods in the order of merit as follows: progressive part, reversed repetitive part, direct repetitive part, pure part, and whole (returns allowed); the writer found the order to be whole, direct repetitive part, pure part, progressive part, and reversed repetitive part, with little advantage for the

progressive part over the reversed repetitive part procedure. The order obtained by Pechstein seems to the writer to be in general what should be expected under the conditions of his experiment. Beginning with rats lacking experience in maze running, those part methods in which the learning problem gradually became more complex would of necessity be more effective in building up the food association, overcoming unfavorable emotional reactions, establishing general maze habits, and preparing the animal for the increasing length of path due to the small increments added from time to time. Animals already trained to run all kinds of maze lengths would have those items mastered in advance. The problem for them would include only the learning of the maze pattern involved and not, in addition, the items named above. Of the two methods found by Pechstein to be best, the progressive part and the reversed repetitive part, one would expect the former to be superior to the latter, the forward learning or the passing from the familiar into the new to be better than the reverse. As stated by Cameron (4, 29), "the tendency in psychology to-day is toward a recognition of the relationship existing between the total form of the stimulating situation and the adequacy of the response." In going from the familiar into the strange the animal began with the pattern which had already been built up, that is, with the total form unimpaired. In going from the strange into the familiar, the pattern already acquired was broken up and the learner had to rebuild his pattern anew. When the problem had been reduced to the single task of learning a specific pattern and the results were not obscured by other factors, the difference was clear. In the tests of the reversed repetitive part and the progressive part methods described in this paper, where the variable factors of emotional tone, etc. had been eliminated and the only learning problem present was that of the specific maze design, the animals found it more difficult to run from the new into the already-learned part without error in the latter than to combine two previously mastered sections and run them together without error in either. In the former they were obliged to reconstruct the total form anew; in the latter the patterns learned seemed to become functional parts of the new

whole. In learning by the direct repetitive part method, the established pattern was not necessarily disorganized with the addition of each new increment, as in the reversed repetitive part method. On the other hand, the excessive amount of retracing points to probable fear of the new and tendency to retrace, which in the progressive part method had been obviated by having each part learned separately before it became a part of a larger whole. Which of these two factors—disorganization of established pattern or emotional disturbance—is the more important is not known.

When we consider the two methods which Pechstein found least effective, the pure part and the whole, we find again that his results are what one would expect with untrained animals. In the pure part method the animal, during the learning of the earlier parts, seems to have overcome the unfavorable emotional tone and to have become accustomed to the maze situation as before. But at the same time he apparently formed the habit of making short runs and this habit tended to hamper him in making the adaptation to the longer path when he was suddenly transferred from running the last quarter to running the maze as a whole. In the whole method the inexperienced animal was set to running the longer path with even less preparation for it than was provided in the pure part procedure. Much retracing resulted. This obviously was due, not only to the fact that the animal was transferred abruptly from no run at all to a long run, but also to the several unmeasurable variable factors present because untrained animals were used. The presence of these factors makes it impossible to compare the whole procedure as employed by Pechstein and as employed by the writer.

From such considerations we may suggest that the advantage for the whole over the part procedures as used in the experiments described in this paper lies in large part in the following facts: the unity of total pattern was maintained throughout the entire learning period; there was but one learning act instead of four, five or seven, as in the part procedures; and learning was always in the forward direction, the direction in which it had to function, and never reversed. The second and third points are perhaps only special cases of the first. In the modified reversed repetitive

part procedure the parts were not thoroughly learned, less energy was expended at small return, and this procedure most nearly approached the whole in effectiveness. In learning by the direct repetitive part method there was advantage in that learning was in the forward direction and cumulative and the distances involved became gradually longer, but there was also some disadvantage due to the fact that the process was divided into four separate learning acts. In the progressive part and reversed repetitive part methods, which differed little in effectiveness, the former had the disadvantage of requiring a larger number of separate learning acts, the latter of requiring learning in the reverse direction from that in which it must ultimately function. The pure part method had the advantage of requiring fewer learning acts than the progressive part method but more than the direct repetitive part method. In comparison with the reversed repetitive part method it had the advantage of requiring learning in the forward direction, the direction in which the learning must ultimately function. Hence the order—whole, modified reversed repetitive part, direct repetitive part, pure part, progressive part, and reversed repetitive part—seems to be the logical order of effectiveness for methods used with trained animals in maze learning.

The results of this experiment are in disagreement with those obtained by Pechstein again in respect to compatibility of parts learned as parts with other parts or with the whole. Pechstein found that "they may function perfectly as parts, in any successive combination of parts, or in the entire motor series" (18). It has already been pointed out that such was not the case in the experiments described. Each part when combined with another or when combined with all the others to form the whole, did not at once function perfectly, but in its new relationship required considerable practice for mastery. It seems probable that the similarities among parts in Pechstein's maze—the general principle governing options at junctions, the similarities in length, arrangement and character of true paths in the different parts and of the character and distances of culs de sac—account for this difference in results. In mazes where each part was unique,

where no specific details of patterns could be carried over to form part of another pattern, the results show that there was no such immediately functioning compatibility among parts.

It is possible, too, that individual differences among the animals may have affected the results obtained by Pechstein. Different rats were used in the whole groups and in the part groups and new groups were used for each of the methods tested. In the present experiment the influence of individual differences was obviated by having each rat serve in both groups for each of the comparisons made between the whole and a part procedure. It seems apparent to those who work with rats that the individual differences are sufficiently great that they cannot be regarded as negligible, but further experimentation is necessary before we can measure exactly the degree of influence of that factor.

Summarizing the results of this experiment we find:

1. The whole method proved to be superior to either the pure part, progressive part, reversed repetitive part, modified reversed repetitive part, or direct repetitive part methods for rats in learning maze patterns.

2. Practice on parts and on part combinations before running the whole contributed to learning, but did not save enough to compensate for the extra energy required.

3. Some important factors in causing waste in part learning were

- a. Breaking up the unity of the total pattern.

- b. Increasing the number of separate learning acts.

- c. Learning in a direction opposite to that in which the learning must ultimately function.

4. Compatibility of parts learned as parts when required to function with other parts or with the whole was not immediate, but required practice of the part in its new relationship.

5. Trained learners did not acquire increasing facility in learning problems of similar type and of comparable difficulty. They had attained a considerable uniformity of performance.

6. The mastery of one part did not affect either positively or negatively the mastery of others when the problems were unique in character.

7. The influence of distribution of repetitions on amount of energy required for learning for immediate recall is in need of further experimental study.

8. Individual differences among learners is a probable factor in learning efficiency regardless of method employed.

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